

# UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No. 1541.1001/GMG

First Named Inventor or Application Identifier:

John McCorkle

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**APPLICATION ELEMENTS**

See MPEP chapter 600 concerning utility patent application contents.

**ADDRESS TO: Assistant Commissioner for Patents**  
**Box Patent Application**  
**Washington, DC 20231**

1. ☒ Fee Transmittal Form
2. ☒ Specification, Claims & Abstract ..... [ Total Pages: 33 ]
3. ☒ Drawing(s) (35 USC 113) ..... [ Total Sheets: 20 ]
4. ☐ Oath or Declaration ..... [ Total Pages:    ]
  - a. ☐ Newly executed (original or copy)
  - b. ☐ Copy from a prior application (37 CFR 1.63(d)) (for continuation/divisional with Box 17 completed)
    - i. ☐ **DELETION OF INVENTOR(S)**  
Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
5. ☐ Incorporation by Reference (usable if Box 4b is checked)  
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. ☐ Microfiche Computer Program (Appendix)
7. ☐ Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
  - a. ☐ Computer Readable Copy
  - b. ☐ Paper Copy (identical to computer copy)
  - c. ☐ Statement verifying identity of above copies

**ACCOMPANYING APPLICATION PARTS**

8. ☐ Assignment Papers (cover sheet & document(s))
9. ☐ 37 CFR 3.73(b) Statement (when there is an assignee)    ☐ Power of Attorney
10. ☐ English Translation Document (if applicable)
11. ☐ Information Disclosure Statement (IDS)/PTO-1449    ☐ Copies of IDS Citations
12. ☐ Preliminary Amendment
13. ☒ Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
14. ☐ Small Entity Statement(s)    ☐ Statement filed in prior application, status still proper and desired.
15. ☐ Certified Copy of Priority Document(s) (if foreign priority is claimed)
16. ☐ Other:

**17. If a CONTINUING APPLICATION, check appropriate box and supply the requisite information:**☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No:        /       **18. CORRESPONDENCE ADDRESS**

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# NEW APPLICATION FEE TRANSMITTAL

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## FEE CALCULATION (fees effective 12/29/99)

| CLAIMS   | (1) FOR | (2) NUMBER FILED | (3) NUMBER EXTRA | (4) RATE                      | (5) CALCULATIONS |
|--|---------|------------------|------------------|-------------------------------|------------------|
| TOTAL CLAIMS   | 26      | - 20 =           | 6                | X \$ 18.00 =                  | \$ 108.00        |
| INDEPENDENT CLAIMS   | 4       | - 3 =            | 1                | X \$ 80.00 =                  | 80.00            |
| MULTIPLE DEPENDENT CLAIMS (any number; if applicable)                            |         |                  |                  | + \$270.00 =                  |                  |
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**SUBMITTED BY: STAAS & HALSEY LLP**

Typed Name

Gene M. Garner, II

Reg. No.

34,172

Signature



Date

October 10, 2000

LEAKAGE NULLING RECEIVER CORRELATOR STRUCTURE AND  
METHOD FOR ULTRA WIDE BANDWIDTH COMMUNICATION  
SYSTEM

Cross Reference to Related Application

5           The present document contains subject matter related to that disclosed  
in the following commonly owned, and co-pending U.S. Patent Applications:  
Serial No. 09/209,460 filed December 11, 1998, entitled ULTRA WIDE  
BANDWIDTH SPREAD-SPECTRUM COMMUNICATIONS SYSTEM  
(Attorney Docket No. 10188-0001-8); Serial No. 09/633,815 filed August 7,  
10   2000, entitled ELECTRICALLY SMALL PLANAR UWB ANTENNA  
(Attorney Docket No.10188-0005-8); Serial No. 09/563,292 filed May 3,  
2000, entitled PLANAR ULTRA WIDE BAND ANTENNA WITH  
INTEGRATED ELECTRONICS (Attorney Docket No. 10188-0006-8);  
Serial No. 60/207,225 filed May 26, 2000, entitled ULTRA WIDEBAND  
15   COMMUNICATION SYSTEM AND METHOD (Attorney Docket No.

BANDWIDTH NOISE CANCELLATION MECHANISM AND METHOD  
(Attorney Docket No.193517US8); Serial No. 60/217,099 filed July 10,  
2000, entitled MULTIMEDIA WIRELESS PERSONAL AREA NETWORK  
(WPAN) PHYSICAL LAYER SYSTEM AND METHOD (Attorney Docket  
No.194308US8PROV); Serial No. XX/XXX,XXX filed October 10, 2000,  
entitled SYSTEM AND METHOD FOR BASEBAND REMOVAL OF  
NARROWBAND INTERFERENCE IN ULTRA WIDEBAND SIGNALS  
(Attorney Docket No.194381US8); Serial No. XX/XXX,XXX filed October  
10, 2000, entitled MODE CONTROLLER FOR SIGNAL ACQUISITION  
AND TRACKING IN AN ULTRA WIDEBAND COMMUNICATION  
SYSTEM (Attorney Docket No. 194588US8); Serial No. XX/XXX,XXX  
filed October 10, 2000, entitled ULTRA WIDEBAND COMMUNICATION  
SYSTEM, METHOD, AND DEVICE WITH LOW NOISE PULSE  
FORMATION (Attorney Docket No. 195268US8); Serial No.  
XX/XXX,XXX filed October 10, 2000, entitled ULTRA WIDE  
BANDWIDTH SYSTEM AND METHOD FOR FAST  
SYNCHRONIZATION (Attorney Docket No. 195269US8); Serial No.  
XX/XXX,XXX filed October 10, 2000, entitled ULTRA WIDE

BANDWIDTH SYSTEM AND METHOD FOR FAST

SYNCHRONIZATION USING SUB CODE SPINS (Attorney Docket No.

195272US8); Serial No. XX/XXX,XXX filed October 10, 2000, entitled

ULTRA WIDE BANDWIDTH SYSTEM AND METHOD FOR FAST

5 SYNCHRONIZATION USING MULTIPLE DETECTION ARMS (Attorney

Docket No. 195273US8); Serial No. XX/XXX,XXX filed October 10, 2000,

entitled METHOD AND SYSTEM FOR ENABLING DEVICE

## FUNCTIONS BASED ON DISTANCE INFORMATION (Attorney Docket

No. 195671US8); Serial No. XX/XXX,XXX filed October 10, 2000, entitled

10 CARRIERLESS ULTRA WIDEBAND WIRELESS SIGNALS FOR

CONVEYING APPLICATION DATA (Attorney Docket No. 196108US8);

Serial No. XX/XXX,XXX filed October 10, 2000, entitled SYSTEM AND

METHOD FOR GENERATING ULTRA WIDEBAND PULSES (Attorney

Docket No. 197023US8); Serial No. XX/XXX,XXX filed October 10, 2000,

15 entitled ULTRA WIDEBAND COMMUNICATION SYSTEM, METHOD,

AND DEVICE WITH LOW NOISE RECEPTION (Attorney Docket

No.197024US8); and Serial No. XX/XXX,XXX filed October 10, 2000.

entitled A LOW POWER, HIGH RESOLUTION TIMING GENERATOR

FOR ULTRA-WIDE BANDWIDTH COMMUNICATION SYSTEMS

20 (Attorney Docket No. 195670US8), the entire contents of each of which

being incorporated herein by reference.

The entire contents of Lathi, "Modern Digital and Analog Communications Systems," Holt, Rinehart and Winston, 1998 is incorporated herein by reference.

## BACKGROUND OF THE INVENTION

### 5 Field of the Invention

The present invention is directed to ultra wide bandwidth communication systems and, more particularly, to a receiver included in ultra wide-band communications systems.

### Description of the Related Art

10 An ultra wide bandwidth spread-spectrum communications system is disclosed in U.S. Utility Patent Application Serial No. 09/209,460 filed December 11, 1998. In the ultra wide bandwidth spread-spectrum communication system disclosed in the foregoing application, data is transmitted between a transmitter and a receiver through multiple pathways.

15 Transmission of data from a transmitter to a receiver through multiple pathways is referred to as multi-path communications.

The transmitted data is encoded by the transmitter using sequences of N wavelets of particular shapes and positions. Each of the sequences of N

wavelets is referred to as an N-length code and represents one bit of digital data, either logical "1" or logical "0". Whether a particular sequence of wavelets represents a logical "1" or a logical "0" is selected arbitrarily according to the source data at the transmitter. For example, a logical "1" would be represented by the sequence of wavelets shown in Figure 1A, while a logical "0" would be represented by a the same sequence of wavelets inverted as shown in Figure 1B.

As shown in Figures 1A and 1B, the period of each wavelet of each waveform RF is 500 picoseconds (ps), with some arbitrary delay occurring between each wavelet referred to as a chip period. That is, a chip period refers to time from one wavelet to a corresponding location on the next wavelet, such as center-to-center. The N-length code is transmitted between  $t = t_0$  and  $t = T$ .

Figure 2 shows a receiver correlator structure 10 which receives data organized into N-length codes. The data, carried on signal RF, impinges on an antenna 12, and is transmitted to coupled mixer 14. Mixer 14 also receives a local oscillator signal, LO, generated by a wavelet generator (not shown in Figure 2).

Signal LO is a pulse stream divided into N-length codes, matched in time to the N-length codes of signal RF. Each N-length code of signal LO represents the same logical value as the prior four-length code of signal LO. That is, the signal LO provides the same value, either logical "0" or logical

“1”code as sent by the transmitting source device, to mixer 14. Mixer 14 mixes signal RF with signal LO to produce signal  $IF = RF * LO$ .

5 An example of a waveform for signal LO, having a four-length code corresponding to logical “0”code, is shown in Figure 1B traveling between time  $t=t_0$  and  $t=T$ .

Figure 3 shows the simplest code in which every chip is the same.

10 Figures 4A and 4B show example waveforms corresponding to signal IF at the output of mixer 14. The resultant IF waveform shown in Figure 4A is produced when signal RF, having a value of logical “1” code shown in Figure 1A, is mixed by mixer 14 with signal LO also having a value of logical “1” code. The resultant IF waveform shown in Figure 4B is produced when signal RF having a value of logical “0” code shown in Figure 1B is mixed by mixer 14 with signal LO having a value of logical “1” code.

15 Signal IF is then integrated by integrator 16 and, subsequently, converted to a digital signal D by analog-to-digital (A/D) converter 18. Digital signal processor (DSP) 20 then removes noise from the resultant integrated digital signal by implementing algorithms known to one of ordinary skill in the art.

20 Mixer 14, integrator 16, analog-to-digital convertor 18 and digital signal processor 20 are conventional components.

Mixer 14 and integrator 16 comprise, ideally, a mathematically matched filter for signal RF. Moreover, integrator 16 is aligned correctly



with each bit of data, and as would be apparent to one of ordinary skill in the art, will either ramp up or ramp down, depending upon the value corresponding to a particular bit integrated by integrator 16.

Since imperfect isolation occurs between signal LO and signal RF at mixer 14, resulting in leakage current 22 between signal LO and signal RF, a bias in signal IF is included at the output of mixer 14.

Figures 5A-5C show graphs of relative values of signals IF, I, and D shown in Figure 2. As shown in Figures 5A-5C, if signal IF is as shown in Fig. 4A, then the waveform of signal I would appear as shown in Figure 5B, and the waveform of signal D would appear as shown in Figure 5C. The waveform of signal I shown in Figure 5B includes an upward slope from 0V to 1V, from 1V to 2V, etc. due to both DC and AC components present in signal I, which were introduced by signal LO into mixer 14 and integrated by integrator 16.

At time  $t = t_0$ , and at each subsequent sampling point through  $t=T$  executed by integrator 16, the value of signal I increases by 1, but that increase is a sloped increase due to DC components included in I, until a value of "4" is reached at time  $t=T$ . Between  $t=t_0$  and  $t=T$ , the value of  $D_i$  is 0. At time  $t=T$ , A/D 18 samples I and increases the value of D to  $D=4$ . That is,  $D_{i+1}=4$ . Thereafter, the integrator 16 is reset to ground causing D to be reset to 0. That is,  $D_{i+2} = 0$ .

Referring again to Figure 2, when signal LO is transmitted to mixer 14, leakage current 22 results in a DC offset (or bias) being provided to signal IF at the output of mixer 14, and the resultant DC offset is integrated by integrator 16. Moreover, the value of signal LO is relatively large (being typically in the range of volts) compared to the value of signal RF (being typically in the range of microvolts), making it difficult for receiver correlator structure 10 to distinguish between signal LO and signal RF after signals LO and RF are mixed by mixer 14.

More particularly, signal LO interferes with signal RF by coupling to RF, by radiating into the air and thus impinging upon antenna 12, and by radiating to and bouncing back from antenna 12.

Moreover, signal LO when provided to mixer 14 causes the above-mentioned bias to change randomly over time, resulting in mixer 14 having an output quantity of noise proportional to  $1/f$ , where  $f$  is a frequency.

A problem with the ultra wide bandwidth receivers of the related art is that the mixer may transmit a leakage current from the local oscillator signal (which is typically in the range of microvolts) to the input of the mixer which receives the pulses, resulting in a DC offset (or bias) from the leakage current being provided at the output of the mixer. This bias then propagates as noise through the rest of the receiver, and interferes with the decoding of the information carried on the pulses.

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It is another object of the invention to eliminate  $1/f$  noise from all mixer leakage terms and mixing terms and non-linearities.

The above objects can be attained by a system that receives a sequence of wavelets that are not back to back but have sufficient spacing  $\tau_s$  as input signal RF and as a local oscillator signal LO.

More particularly, the present invention is a receiver correlator structure and corresponding method. The receiver correlator structure of the present invention comprises an antenna, a mixer, a bandpass filter, and a converter. The antenna receives an ultra wide bandwidth signal comprising a sequence of wavelets of particular shapes and positions. The mixer is coupled to the antenna and receives from the antenna the ultra wide bandwidth signal and mixing the ultra wide bandwidth signal with a local ultra wide bandwidth signal comprising a sequence of wavelets of particular shapes and positions correlated to the sequence of wavelets of particular shapes and positions of the received ultra wide bandwidth signal. The bandpass filter is coupled to the mixer output and receives the mixed ultra wide bandwidth signal, removing the DC components therefrom. The bandpass filter outputs a resultant signal in which an initial peak of the resultant signal is proportional to energy included in the mixed ultra wide bandwidth signal and post signal decay of the resultant signal to zero occurs in  $\tau_s$  time. The convertor is coupled to the bandpass filter and converts the

resultant signal at the initial peak to a digital output signal. The convertor is coupled optionally to a digital signal processor. The converter is one of an analog-to-digital converter, a comparator, or a sample and hold circuit coupled in series to an integrator then to an analog-to-digital converter.

5           These together with other objects and advantages which will be subsequently apparent, reside in the details of construction and operation as more fully hereinafter described and claimed, reference being had to the accompanying drawings forming a part hereof, wherein like numerals refer to like parts throughout.

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#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1A shows a sequence of wavelets (or chips) representing a logical "1" code.

Figure 1B shows a sequence of wavelets (chips) representing a logical "0" code.

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Figure 2 shows a receiver correlator structure.

Figure 3 shows an example of a waveform output by a local oscillator LO and input to the receiver correlator structure shown in Figure 2.

Figures 4A and 4B show example waveforms of signal IF shown in Figure 2.

Figures 5A, 5B, and 5C show graphs of relative values of signals IF, I, and D shown in Figure 2.

Figure 6 shows a receiver correlator of the present invention.

Figure 7 shows an example of a waveform presented by local  
5 oscillator LO to the receiver correlator of the present invention.

Figure 8 shows a series of signals RF input to the receiver correlator of the present invention shown in Figure 6.

Figure 9A shows a detailed diagram of the receiver correlator of the present invention.

10 Figure 9B shows another embodiment of the receiver correlator of the present invention.

Figures 9C, 9D, and 9E show alternate embodiments of converter 44.

Figure 10A and 10 B show examples of waveform IF at the output of mixer 40 of the receiver correlator of the present invention.

15 Figure 11A shows band pass filter 42 being applied to signal IF.

Figure 11B shows the resultant waveform at the output of band pass filter 42.

Figure 12 shows a an example of a series of wavelets transmitting data to the receiver correlator structure of the present invention.

20 Figure 13A shows one embodiment of band pass filter 42.

Figure 13B shows another embodiment of band pass filter 42.

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Figure 14 shows a table of outputs by receiver correlator 10 of the related art and receiver correlator 30 of the present invention.

Figure 15 shows an ultra wide bandwidth communication system in which the receiver correlator of the present invention would be included.

5           Figure 16 shows a diagram of a UWB Waveform Correlator of the ultra wide bandwidth communication system shown in Figure 15.

Figure 17 shows a diagram of a Radio Controller and Interface of the ultra wide bandwidth communication system shown in Figure 15.

10                   DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 6 shows a receiver correlator 30 of the present invention which receives from transmitter 32 an ultra wide bandwidth signal RF. Ultra wide bandwidth signal RF comprises a sequence of wavelets of particular shapes and positions. Transmitter 32 is disclosed in Serial No. XX/XXX,XXX filed  
15   October 10, 2000, entitled SYSTEM AND METHOD FOR GENERATING ULTRA WIDEBAND PULSES (Attorney Docket No. 197023US8), incorporated herein by reference, and in Serial No. XX/XXX,XXX filed  
October 10, 2000, entitled ULTRA WIDEBAND COMMUNICATION SYSTEM, METHOD, AND DEVICE WITH LOW NOISE PULSE  
20   FORMATION (Attorney Docket No. 195268US8), incorporated herein by reference.

In addition, the receiver correlator structure 30 of the present invention receives an ultra wide bandwidth signal LO. Ultra wide bandwidth signal LO comprises a sequence of wavelets of particular shapes and positions corresponding to ultra wide bandwidth signal RF. Ultra wide bandwidth signal LO is produced by timing generator 36 as disclosed in co-pending Application Serial No. XX/XXX,XXX filed October 10, 2000, entitled A LOW POWER, HIGH RESOLUTION TIMING GENERATOR FOR ULTRA-WIDE BANDWIDTH COMMUNICATION SYSTEMS (Attorney Docket No. 195670US8), incorporated herein by reference. More particularly, timing generator 36, based upon inputs of frequency, phase, and time dither, prompts wavelet generator 34 to generate signal LO, which is time-aligned with signal RF.

Wavelet generator 34 is disclosed in co-pending Application Serial No. XX/XXX,XXX filed October 10, 2000, entitled SYSTEM AND METHOD FOR GENERATING ULTRA WIDEBAND PULSES (Attorney Docket No. 197023US8), incorporated herein by reference.

The shape of the wavelet of signal LO generated by wavelet generator 34 can vary, with shapes such as biphasic, multi-amplitude, multi-phase, and chirp.

Figure 7 shows an example of a waveform presented by signal LO in Figure 6 . The waveform LO shown in Figure 7 was generated by wavelet generator 34 and has a constant pulse shape.



Figure 8 shows a series of signals  $RF_1$ ,  $RF_2$ ,  $RF_3$ , ... which are wavelets, having a period of  $T_s$ . Each wavelet, or series of wavelets, of ultra wide bandwidth signal RF corresponds to a logical "1" or a logical "0", depending upon the shape of the wavelet of signal RF. That is,  $RF_1$  of Figure 8 could correspond to logical "1" (and signal LO of Figure 7), while  $RF_2$  and  $RF_3$  of Figure 8 could each correspond to logical "0". As shown in Figure 8,  $T_p$  is less than  $T_s$  (the center-to-center clock period), and  $T_{pp}$  (peak to peak) is less than  $T_p$ .  $T_p$  is the width of the wavelet, and is typically twice  $T_{pp}$ . An example of  $T_{pp}$  would be 330 pico-seconds (peak-to-peak); an example of  $T_s$  would be 20 nano-seconds.

Figure 9A shows a more detailed diagram of receiver correlator structure 30 of the present invention. As shown in Figure 9A, signal RF impinges upon antenna 38, and is coupled to mixer 40. Antenna 38 could be a conventional antenna or could be of the structure disclosed in co-pending U.S. Patent Application Serial No. 09/563,292 filed May 3, 2000, entitled PLANAR ULTRA WIDE BAND ANTENNA WITH INTEGRATED ELECTRONICS (Attorney Docket No. 10188-0006-8), incorporated herein by reference.

Mixer 40 receives signal RF and local oscillator signal LO, which is time-aligned with signal RF as discussed in co-pending U.S. Patent Application Serial No. XX/XXX,XXX filed October 10, 2000, entitled

MODE CONTROLLER FOR SIGNAL ACQUISITION AND TRACKING  
IN AN ULTRA WIDEBAND COMMUNICATION SYSTEM (Attorney  
Docket No. 194588US8), incorporated herein by reference, and in Serial No.  
XX/XXX,XXX filed October 10, 2000, entitled ULTRA WIDE  
5 BANDWIDTH SYSTEM AND METHOD FOR FAST  
SYNCHRONIZATION (Attorney Docket No. 195269US8), incorporated  
herein by reference.

In one embodiment, the pulse shape of signal LO can be constant.  
That is, each waveform generated by wavelet generator 34 (shown in Figure  
10 6) is the same as the prior waveform of signal LO, and corresponds to either a  
logical "1" or a logical "0", but does not vary from pulse to pulse.  
Consequently, leakage L (shown in Figure 9) of signal LO between mixer 40  
and antenna 38 is always the same from pulse to pulse of signal LO. This  
leakage L is non-linear, and is removed as discussed herein below.

15 Mixer 40 is, for example, a Mini-circuits ADE-42 MH.

After signals RF and LO are mixed by mixer 40, the resultant, mixed  
signal IF is transmitted from mixer 40 to band pass filter 42. Band pass filter  
42 removes DC components from signal IF. That is, band pass filter 42  
removes any bias introduced by mixer 40 by resetting the bias to 0 in a single  
20 chip period. Thus, in band pass filter 42, the settling time is less than the bit.  
More particularly, band pass filter 42 removes 1/f noise. Band pass filter 42  
is discussed in further detail with reference to Figures 13A and 13B.

Figure 9B shows another embodiment of the present invention which includes adder 43. Adder 43 has a bias voltage  $V_B$ .  $V_B$  is set such that when signal  $RF = 0$ , the output of convertor 44 (if convertor 44 is an analog-to-digital convertor) is 0V at sampling point S. If convertor 44 is a comparator, then  $V_B$  is set such that the comparator has a 50% duty cycle. If  $V_B$  is not set in this way, then DSP 46 would have to estimate  $V_B$  across a series of bits decoded from the wavelets of received ultra wide bandwidth signal RF. However, setting  $V_B$  as described would save time and battery life over having DSP 46 estimate  $V_B$ .

Figure 9C, 9D, and 9E show alternate embodiments of the convertor 44. Figure 9C shows analog-to-digital converter 92; Figure 9D shows comparator 94; and Figure 9E shows sample-and-hold circuit 96 coupled in series to integrator 98, which is coupled in series to analog-to-digital convertor 99.

In one embodiment, integrator 98 would function as a D-latch circuit, in which the integrator would sample a signal input thereto on the rising edge of a clock pulse input to the integrator 98, and transfers to the output of integrator 98 the signals that were integrated since the prior clock pulse. Such an integrator 98 would comprise a ping-pong circuit, which would comprise two integrators functioning during alternate clock periods. An example of such an integrator 98 is disclosed in U.S. Patent Application Serial No. 09/209,460 filed December 11, 1998, entitled ULTRA WIDE

BANDWIDTH SPREAD-SPECTRUM COMMUNICATIONS SYSTEM

(Attorney Docket No. 10188-0001-8), incorporated herein by reference, and  
in U.S. Patent Application Serial No. 09/633,815 filed August 7, 2000,  
entitled ELECTRICALLY SMALL PLANAR UWB ANTENNA (Attorney  
5 Docket No.10188-0005-8), incorporated herein by reference.

An example of waveform IF, at the output of mixer 40, is shown in  
Figure 10A. For the shape of waveform IF shown in Figure 10A, the shape  
of the waveform input in signal RF corresponds to a logical "1", and the  
shape of the waveform input by signal LO also corresponds to a logical "1".

10 Of course, if RF and LO were logically opposite to each other, then the shape  
of waveform IF at the output of mixer 40 would correspond to waveform IF  
shown in Figure 10B.

Moreover, in the signal IF shown in Figures 10A and 10B, the peak-  
to-peak difference between pulses is typically less than 1 nanosecond, though  
15 in some applications could be longer.

Band pass filter 42 accommodates waveform IF as shown in Figure  
10A and in Figure 10B. That is, band pass filter 42 recognizes dynamically  
whether signal IF corresponds to the waveform shown in Figure 10A or  
corresponds to the waveform shown in Figure 10B, and removes the DC  
20 components, and therefore the bias introduced by mixer 40, from either.

Figure 11A shows band pass filter 42 being applied to signal IF, and  
Figure 11B shows resultant signal B, at the output of the band pass filter 42,

after band pass filter 42 is applied to signal IF. That is, signal B corresponds to signal IF, but with DC components present in signal IF removed from signal B by band pass filter 42, and the AC signal leaked by mixer 40 from signal LO, removed at the sampling instant S. Also as shown in Figure 11A, in the receiver correlator of the present invention, the sampling instant S by the convertor 44 occurs at the relative maximum (or peak) or relative minimum of the output waveform from the bandpass filter 42.

As shown in Figure 11A, the settling time of the band pass filter 42 is less than the bit period of the data encoded in signal IF.

Signal B is then transmitted to convertor 44, which samples signal B at each respective peak thereof. That is, convertor 44 samples signal B at sampling points S shown in Figure 11A. Convertor 44 is an analog-to-digital convertor. Alternatively, convertor 44 is a comparator. Alternatively still, convertor 44 is a sample-and-hold circuit coupled in series to an integrator and to an analog-to-digital convertor.

Convertor 44 is biased by  $V_b$  such that the output of the convertor 44 is at the 0-volt threshold (or zero mean), when there is no RF signal or the RF signal is white Gaussian noise. That is, each bit is resolved to 0 by the combination of band pass filter 42 and convertor 44. The Convertor 44 is, for example a Texas instruments TLV 5580.

For pulses (or wavelets) transmitted as signal RF which correspond to logical "1" or logical "0", then output signal OF is output by receiver correlator structure 30 directly from Convertor 44.

Each pulse transmitted as signal RF, and ultimately, as signal IF and  
5 signal B, corresponds to a logical "1" or a logical  
"0" in the embodiment described here and above.

Alternatively, a series of single spike pulses, RF, represent a bit. That is, a series of two consecutive single spike pulse correspond to either logical "1" or logical "0". If a series of single spike pulses corresponds to either  
10 logical "1" or logical "0" then a digital signal processor DSP 46 is placed at the output of Convertor 44. The DSP 46 receives the output signal from Convertor 44 and digitally integrates the output signal. That is, DSP 44 implements an algorithm readily apparent to those of skill in the art, to sum or add the series of pulses such that each series of pulses is determined to be  
15 to correspond to either a logical "1" or a logical "0". DSP 46 is, for example an Intel Pentium™ processor.

Figure 12 shows a series of pulses, RF, which when received by receiver correlator structure 30 of the present invention, resolve through the activities of antenna 38, mixer 40, band pass filter 42, Convertor 44 and DSP  
20 46 as described herein above, to a logical "1". Although the series of pulses RF correspond to logical "1" each single spike pulse is spaced from another single spike pulse by a period of  $T_s$ .

Figure 13A shows an embodiment of band pass filter 42. Referring now to Figure 13A, signal IF enters band pass filter 42 along an input port which is tied to ground through a nine pico-fared capacitor 50 and a 51-ohm resistor 52 and proceeds to 22-nano henry inductor 54. The output of inductor 54 is tied to ground through 51-OHM resistor 56 and 100 nano henry inductor 58 and to 47 Pico-fared capacitor 60, which is input to amplifier ERA-5SM 62. The output of amplifier 62 is tied to ground through 4 pico-fared capacitor 64 and to 22 nano henry inductor 66. The output of inductor 66 is tied, concurrently, to ground through 4 pico-fared capacitor 68, and to a 12-volt power source through 110-ohm resistor 70, which is in parallel with .01 micro-fared capacitor 72, also tied to ground. The output of inductor 66 travels through .01 micro-fared capacitor 74 to become output B.

An alternate embodiment of band pass filter 42 is shown in Figure 13B. Referring now to Figure 13B, input signal IF travels through capacitor 80, the output of which is tied in parallel to capacitor 82, capacitor 84 and ground through capacitor 86. Signal IF continues through capacitor 84 into amplifier 86 and through capacitor 82 to the output of amplifier 86. The output of amplifier 86 is tied through resistor 88 back to the input of amplifier 86 and is output from band pass filter 42 at signal B.

Figure 14 shows a table 90 of outputs by receiver correlator 30 and receiver correlator 10, based upon input signal RF and local oscillator LO.

As shown in Figure 14, when input signal RF corresponds to logical "1" and local oscillator corresponds to logical "1", receiver correlator 30 of the present invention outputs a value of +1, whereas receiver correlator 10 would output a value of  $1+a$ , which is perhaps a value other than +1.

5 Likewise, if RF corresponds to logical "0" and LO corresponds to logical "0", receiver correlator 30 would output +1 whereas receiver correlator 10 would output a value of  $1-b$ , which is also perhaps a value other than +1. In addition, if RF corresponds to logical "1", and LO corresponds to logical "0" receiver correlator 30 outputs -1 and receiver correlator 10 outputs  $-1-b$ ,  
10 which is perhaps a value other than -1. Lastly if RF corresponds to "0" and LO corresponds to "1" receiver correlator 30 outputs -1 and receiver correlator 10 outputs  $-1-a$ , which is also perhaps a value other than -1.

Receiver correlator 10 outputs  $a$  and  $b$  because of the affect of the bias between mixer 14 and antenna 12. Moreover,  $a$  and  $b$  have  $1/f$  noise that  
15 obscures the signal of interest.

The present invention has been described with respect to the above-mentioned components. However, implementation of the above-mentioned functions is not limited in the present invention to the components described. For example, the present invention may be implemented in silicon on a signal  
20 chip or on multiple chips.

An ultra wide bandwidth system (that is, an ultra-wide band trnasceiver) in which the receiver correlator structure of the present invention



could be implemented is shown in Figure 15. The transceiver 100 shown in Figure 15 includes a receiver 112, a transmitter 114, and a Radio Controller and Interface 110. The Receiver 112 includes antenna 102, Front End 104, UWB Waveform Correlator 106, and Timing Generator 108.

5           The Transmitter 114 includes antenna 116, UWB Waveform Generator 118, Timing Generator 108, and Encoder 122.

          The Transceiver 100 is described in further detail in U.S. Application Serial No. XX/XXX,XXX filed October 10, 2000, entitled A LOW POWER, HIGH RESOLUTION TIMING GENERATOR FOR ULTRA-WIDE  
10       BANDWIDTH COMMUNICATION SYSTEMS (Attorney Docket No. 195670US8), incorporated herein by reference.

          The receiver correlator structure 30 of the present invention is incorporated into transceiver 100 as shown in Figures 16 and 17. That is, the mixer 40 and the bandpass filter 42 are included (along with wavelet  
15       generator 34) into UWB waveform correlator 106, and the convertor 44 and the DSP 46 are included in the Radio Controller and Interface 110.

          That is an ultra wide bandwidth communication system of the present invention comprises a transmitter transmitting an ultra wide bandwidth signal comprising a sequence of wavelets of particular shapes and positions, a  
20       wavelet generator generating a local ultra wide bandwidth signal comprising a sequence of wavelets of particular shapes and positions corresponding to the transmitted ultra wide bandwidth signal, and a receiver correlator

structure. The receiver correlator structure comprises an antenna receiving the transmitted ultra wide bandwidth signal, a mixer, coupled to the antenna, receiving from the antenna the received ultra wide bandwidth signal and mixing the ultra wide bandwidth signal with the local ultra wide bandwidth signal, a bandpass filter, coupled to the mixer output, receiving the mixed ultra wide bandwidth signal, removing the DC components therefrom, and outputting a resultant signal, wherein an initial peak of the resultant signal is proportional to energy included in the mixed ultra wide bandwidth signal and post signal decay of the resultant signal to zero occurs in  $T_s$  time, and a convertor, coupled to the bandpass filter, converting the resultant signal at the initial peak to a digital output signal.

The many features and advantages of the invention are apparent from the detailed specification and, thus, it is intended by the appended claims to cover all such features and advantages of the invention which fall within the true spirit and scope of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation illustrated and described, and accordingly all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.


































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outputting a resultant signal, wherein an initial peak of the resultant signal is proportional to energy included in the mixed ultra wide bandwidth signal and post signal decay of the resultant signal to zero occurs in  $\tau_s$  time; and

a convertor, coupled to the bandpass filter, converting the resultant  
5 signal at the initial peak to a digital output signal.

2. The receiver correlator structure as in claim 1, wherein the convertor comprises an analog-to-digital convertor.

3. The receiver correlator structure as in claim 1, wherein the convertor comprises a comparator.

10 4. The receiver correlator structure as in claim 1, wherein the convertor comprises a sample and hold circuit, an integrator, and an analog-to-digital convertor coupled in series.

5. The receiver correlator structure as in claim 1, wherein said local  
ultra wide bandwidth signal comprises a constant logic level equivalent  
15 wavelet shape.

6. The receiver correlator structure as in claim 1, further comprising a digital signal processor coupled to the convertor and integrating the digital output signal over an N-length sequence of said wavelets.

7. The receiver correlator structure as in claim 1, wherein the resultant output signal voltage polarity corresponds to a logical "1" or a logical "0", based upon shapes of the received ultra wide bandwidth signal and the local ultra wide bandwidth signal.

8. The receiver correlator structure as in claim 1, wherein the receiver correlator structure receives, decodes, and outputs information encoded in a series of the received ultra wide bandwidth signal wavelets.

9. The receiver correlator structure as in claim 8, wherein each of the wavelets included in the series has the same period as each prior wavelet included in the series.

10. A method of an ultra wide bandwidth communication system, comprising:

receiving an ultra wide bandwidth signal comprising a sequence of wavelets of particular shapes and positions;

mixing the ultra wide bandwidth signal with a local ultra wide bandwidth signal comprising a sequence of wavelets of particular shapes and positions correlated to the sequence of wavelets of particular shapes and positions of the received ultra wide bandwidth signal;

5            removing the DC components therefrom, and outputting a resultant signal, wherein an initial peak of the resultant signal is proportional to energy included in the mixed ultra wide bandwidth signal and post signal decay of the resultant signal to zero occurs in  $\tau_s$  time; and

10            converting the resultant signal at the initial peak to a digital output signal.

11. The method as in claim 10, further comprising:  
integrating the resultant signal.

12. The method as in claim 10, wherein the removing comprises  
15 removing from the mixed signal a bias signal introduced by the mixing.

13. The method as in claim 10, wherein the resultant output signal voltage polarity corresponds to a logical "1" or a logical "0", based upon shapes of the received ultra wide bandwidth signal and the local ultra wide bandwidth signal.

14. The method as in claim 10, further comprising:

receiving, decoding, and outputting information encoded in a series of the received ultra wide bandwidth wavelets.

15. The method as in claim 12, wherein each of the wavelets

5 included in the series has the same period as each wavelet included in the series.

16. The method in claim 10, wherein the shape of the mixed signal is recognized dynamically and the DC components are removed therefrom.

17. An apparatus comprising:

10 a receiver correlator receiving an ultra wide bandwidth signal  
comprising a sequence of wavelets of particular shapes and positions and a  
local ultra wide bandwidth signal comprising a sequence of wavelets of  
particular shapes and positions correlated to the sequence of wavelets of  
particular shapes and positions of the received ultra wide bandwidth signal,  
15 mixing the received ultra wide bandwidth signal and the local ultra wide  
bandwidth signal, removing DC components from the mixed signal,  
outputting a resultant signal wherein an initial peak of the resultant signal is  
proportional to energy included in the mixed ultra wide bandwidth signal and

[illegible]

5                    an antenna receiving the received ultra wide bandwidth signal;  
                      a mixer coupled to the antenna, receiving the received ultra  
                      wide bandwidth signal and the local ultra wide bandwidth signal, and mixing  
                      the received ultra wide bandwidth signal and the local ultra wide bandwidth  
                      signal;

19. The apparatus as in claim 18, wherein the convertor comprises an  
15 analog-to-digital convertor.

20. The apparatus as in claim 18, wherein the convertor comprises a comparator.



21. The apparatus as in claim 18, wherein the convertor comprises a sample-and-hold circuit coupled in series to an integrator and to an analog-to-digital convertor.

22. The apparatus as in claim 17, wherein the receiver correlator  
5 receives information encoded in the received ultra wide bandwidth signal comprising the sequence of wavelets and outputs digital data corresponding thereto.

23. The apparatus as in claim 17, wherein the receiver correlator  
10 receives information encoded in one of the wavelets of the received ultra wide bandwidth signal and outputs digital data corresponding thereto.

24. The apparatus as in claim 18, wherein the bandpass filter removes from the mixed signal bias current introduced thereto by the mixer.

25. The apparatus as in claim 18, wherein the receiver correlator  
15 further comprises a digital signal processor coupled to the convertor and integrating the output thereof.

26. An ultra wide bandwidth communication system comprising:

a transmitter transmitting an ultra wide bandwidth signal comprising a sequence of wavelets of particular shapes and positions;

a wavelet generator generating a local ultra wide bandwidth signal comprising a sequence of wavelets of particular shapes and positions

5 corresponding to the transmitted ultra wide bandwidth signal; and

a receiver correlator structure comprising:

an antenna receiving the transmitted ultra wide bandwidth signal,

10 a mixer, coupled to the antenna, receiving from the antenna the received ultra wide bandwidth signal and mixing the ultra wide bandwidth signal with the local ultra wide bandwidth signal,

a bandpass filter, coupled to the mixer output, receiving the mixed ultra wide bandwidth signal, removing the DC components therefrom, and outputting a resultant signal, wherein an initial peak of the resultant  
15 signal is proportional to energy included in the mixed ultra wide bandwidth signal and post signal decay of the resultant signal to zero occurs in  $T_s$  time, and

a convertor, coupled to the bandpass filter, converting the resultant signal at the initial peak to a digital output signal.

# LEAKAGE NULLING RECEIVER CORRELATOR STRUCTURE AND METHOD FOR ULTRA WIDE BANDWIDTH COMMUNICATION SYSTEM

## ABSTRACT OF THE DISCLOSURE

A receiver correlator structure for an ultra wide bandwidth communication system includes an antenna, a mixer, a bandpass filter, and a convertor. The receiver receives, via the antenna, an ultra wide bandwidth signal comprising a sequence of wavelets of particular shapes and positions, and transmits the received ultra wide bandwidth signal to the mixer. The mixer also receives and mixes with the received ultra wide bandwidth signal a local ultra wide bandwidth signal comprising a sequence of wavelets of particular shapes and positions correlated to the received ultra wide bandwidth signal. The bandpass filter removes the DC components from the mixed signal, and provides the resultant signal to the convertor. The receiver structure eliminates the local ultra wide bandwidth signal AC bias and DC bias terms and  $1/f$  noise, yet detects long sequences of logical 1's and 0's, and allows operation with reduced bandwidth convertors.

FIGURE 1A

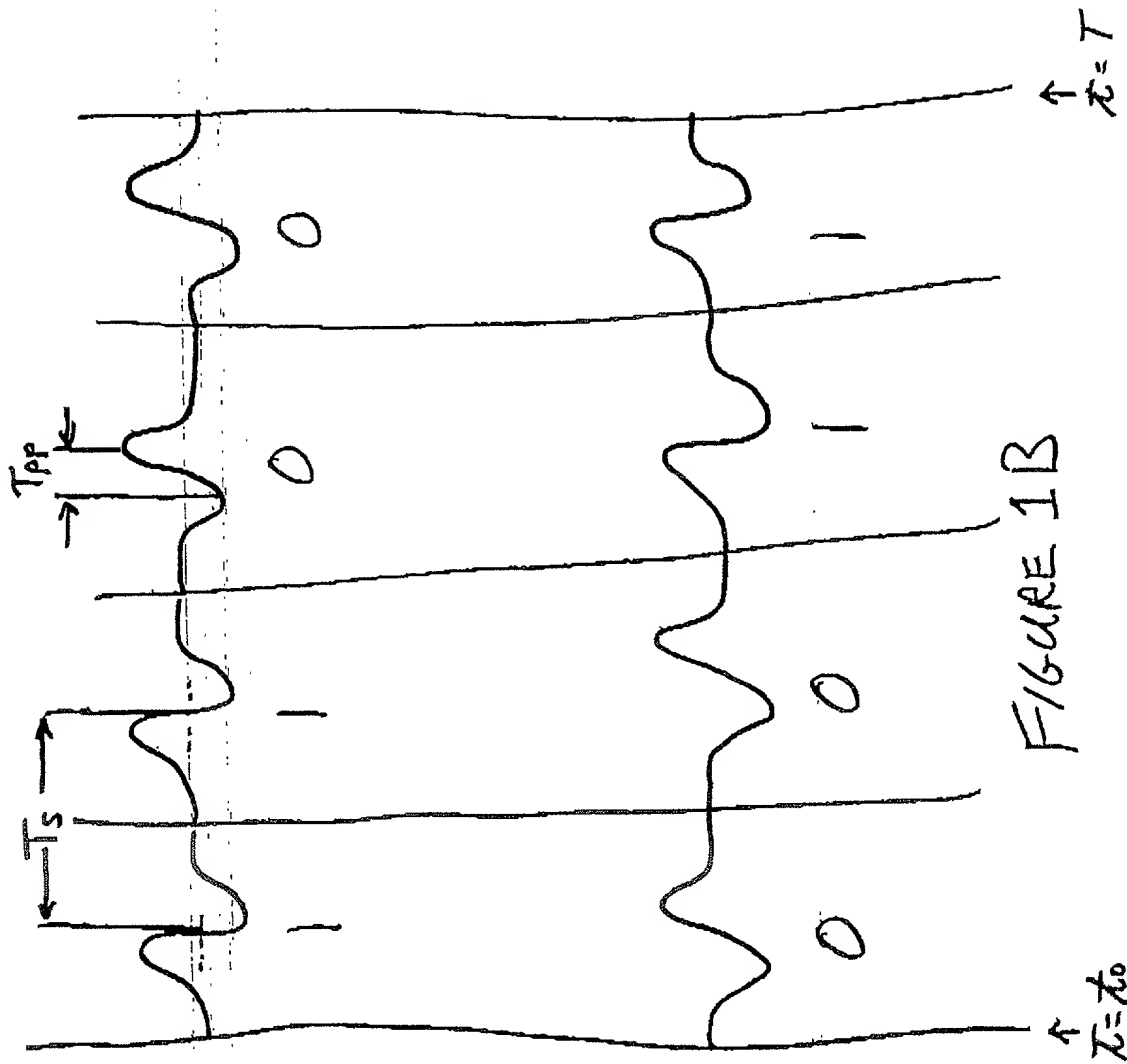


FIGURE 1B

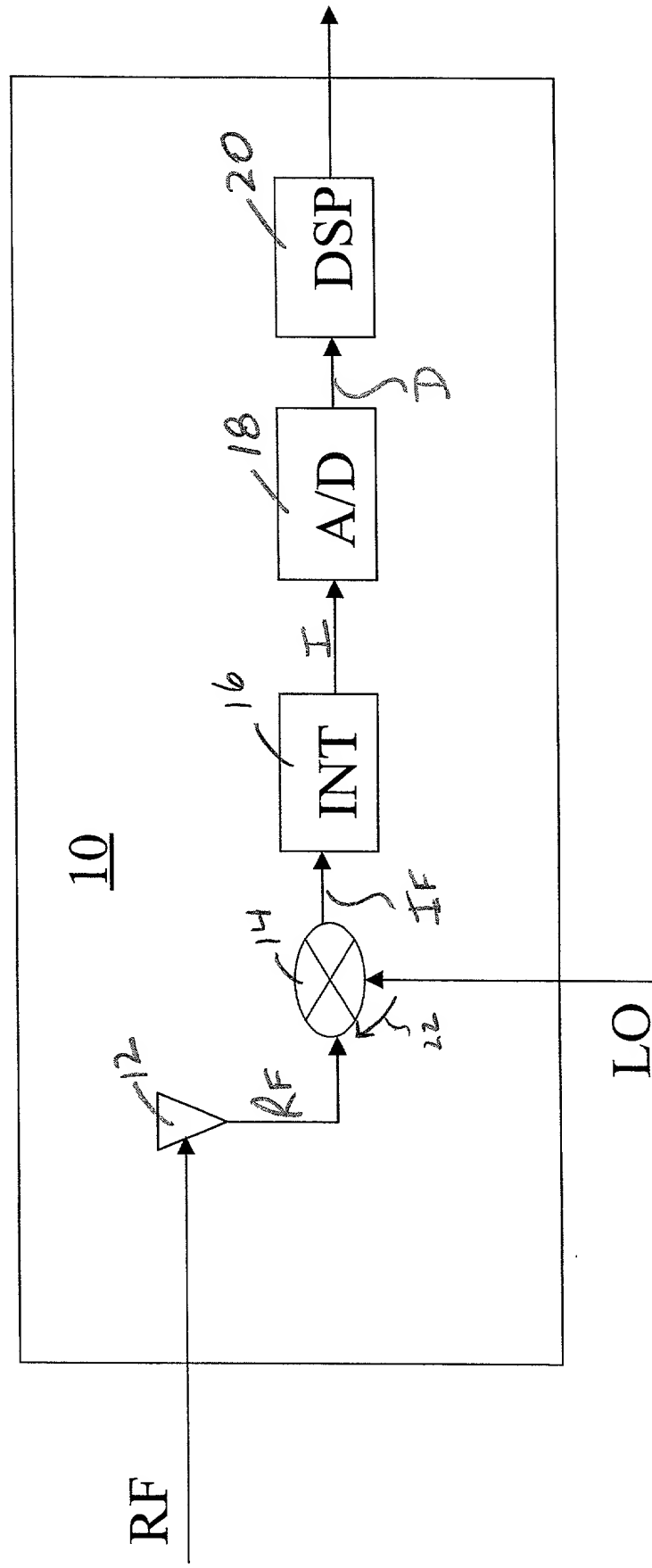


FIGURE 2



FIGURE 4A

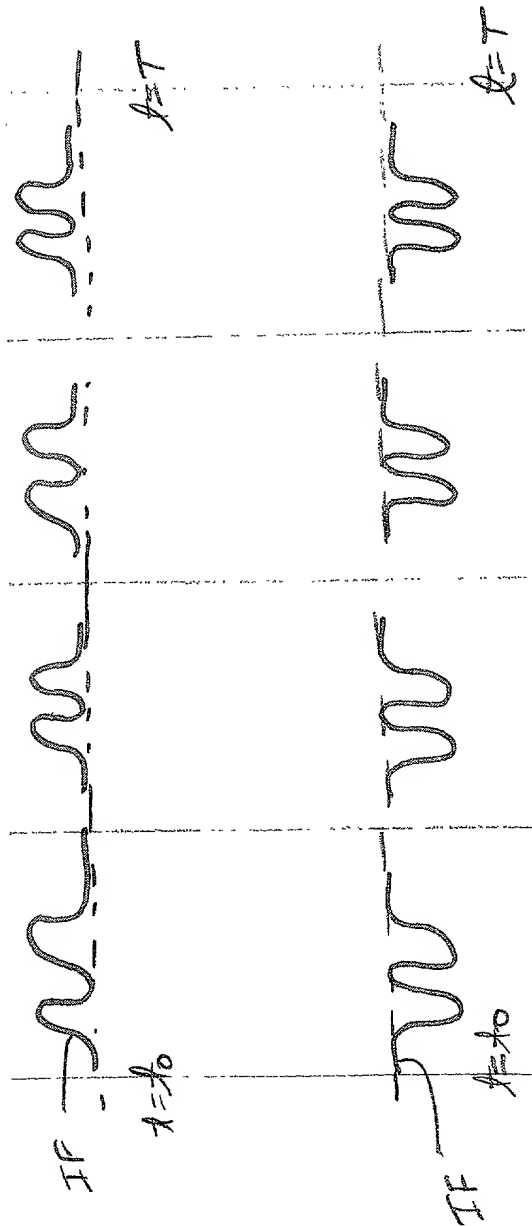


FIGURE 4B





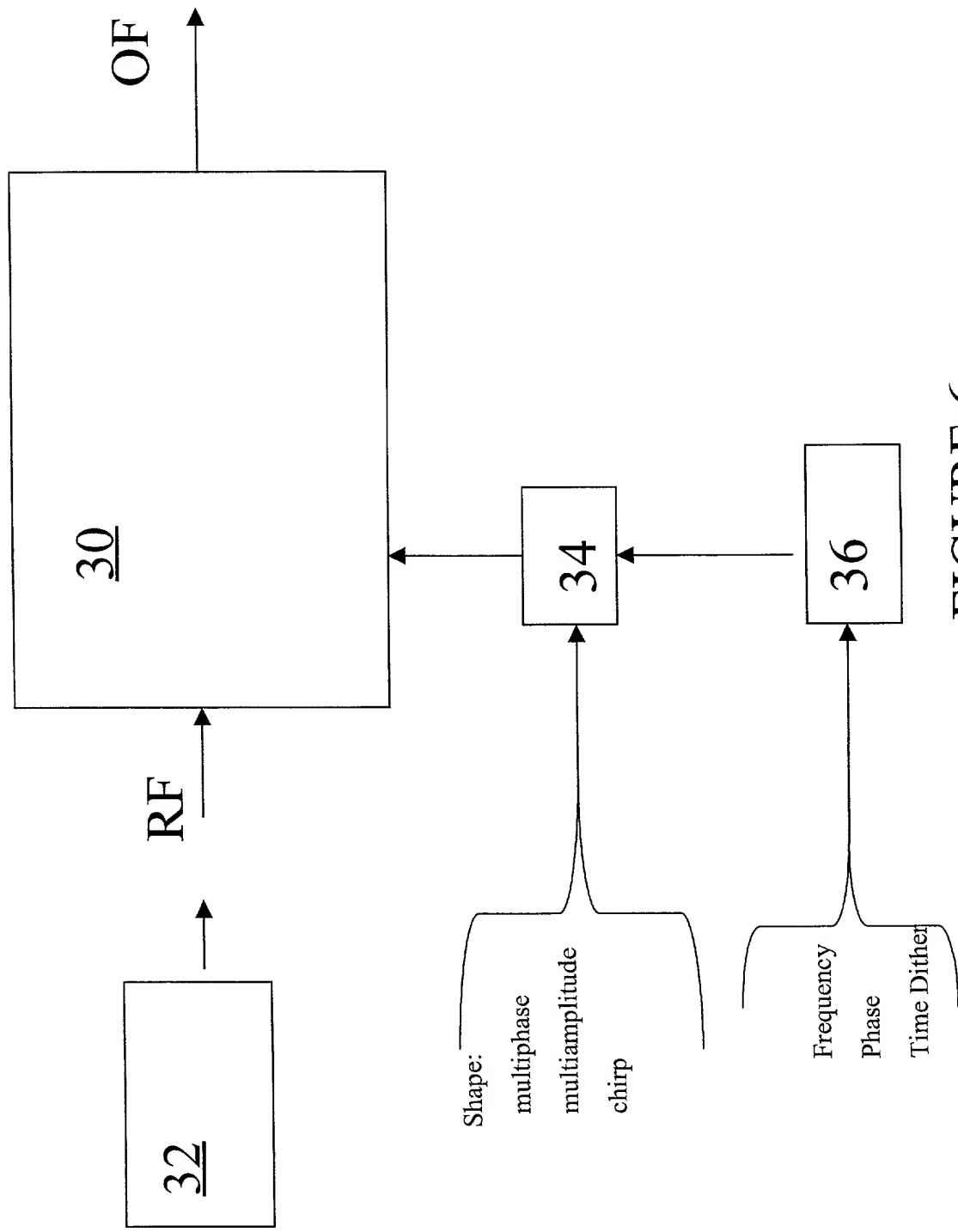
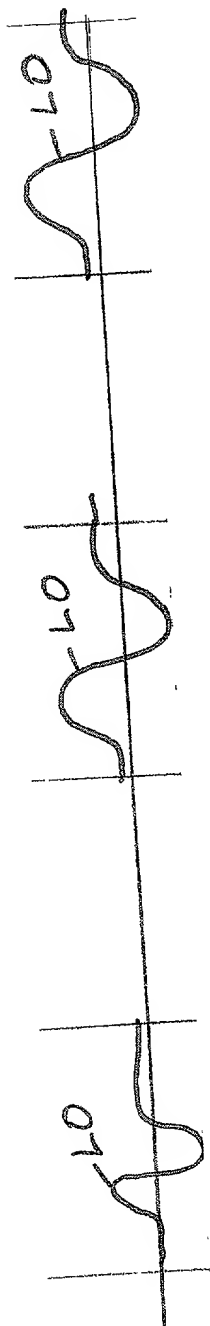


FIGURE 6

09625200 101000



$x=7$

FI GURE 7

$x=7$

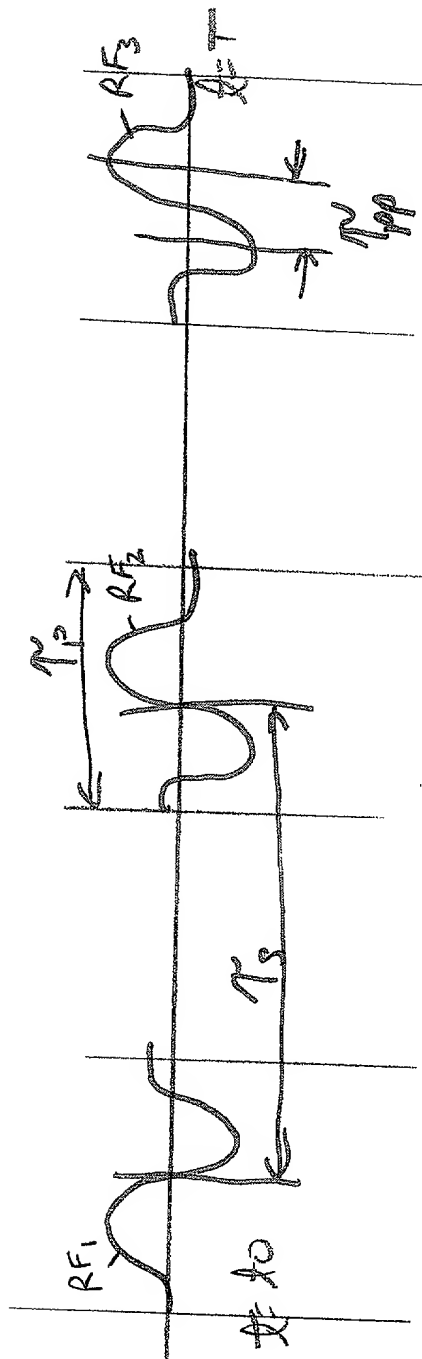


FIGURE 8

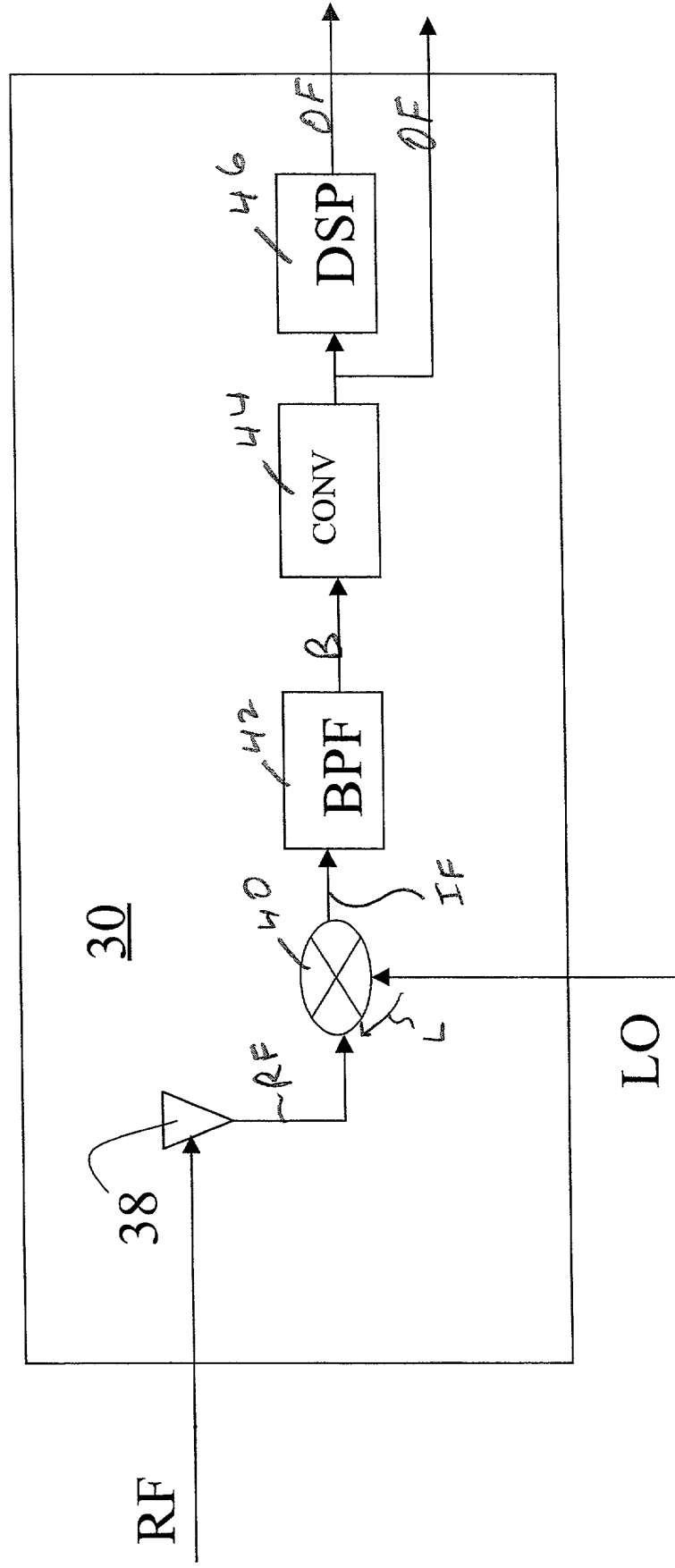


FIGURE 9A



FIGURE 9C

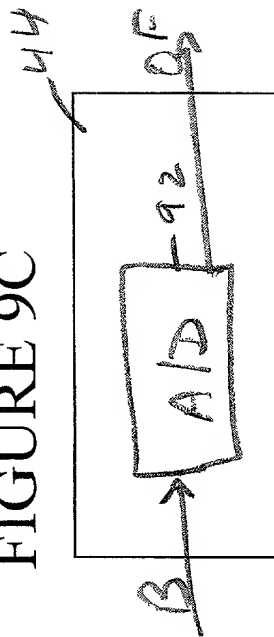


FIGURE 9D

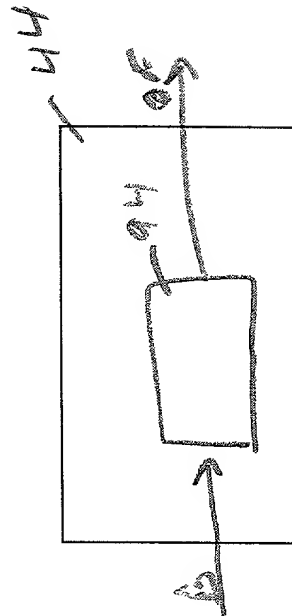
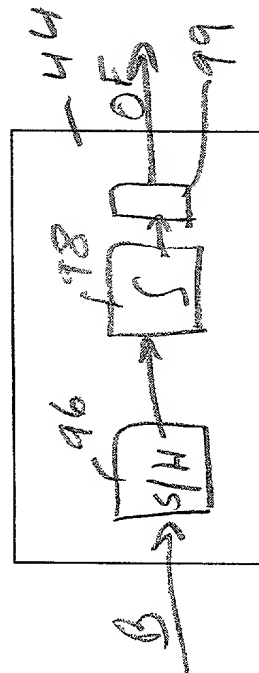


FIGURE 9E



000101" 00252560

FIGURE 10A

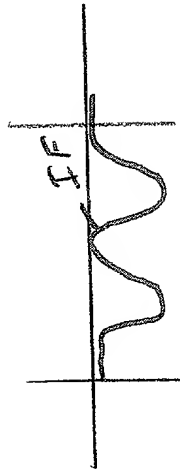


FIGURE 10B

000101" 00258991A  
FIGURE 11A

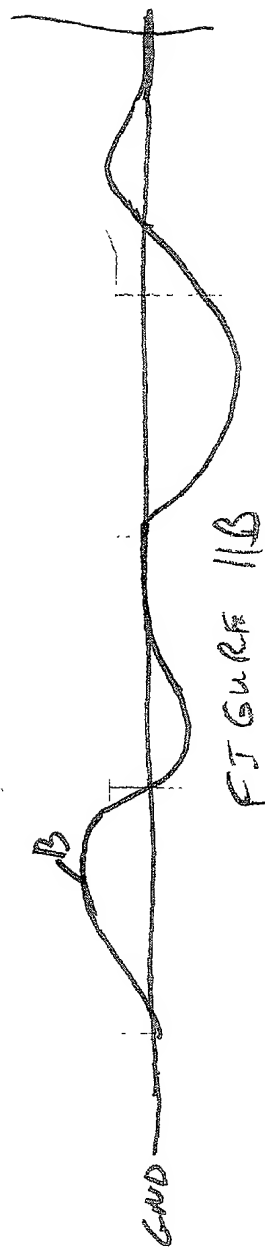
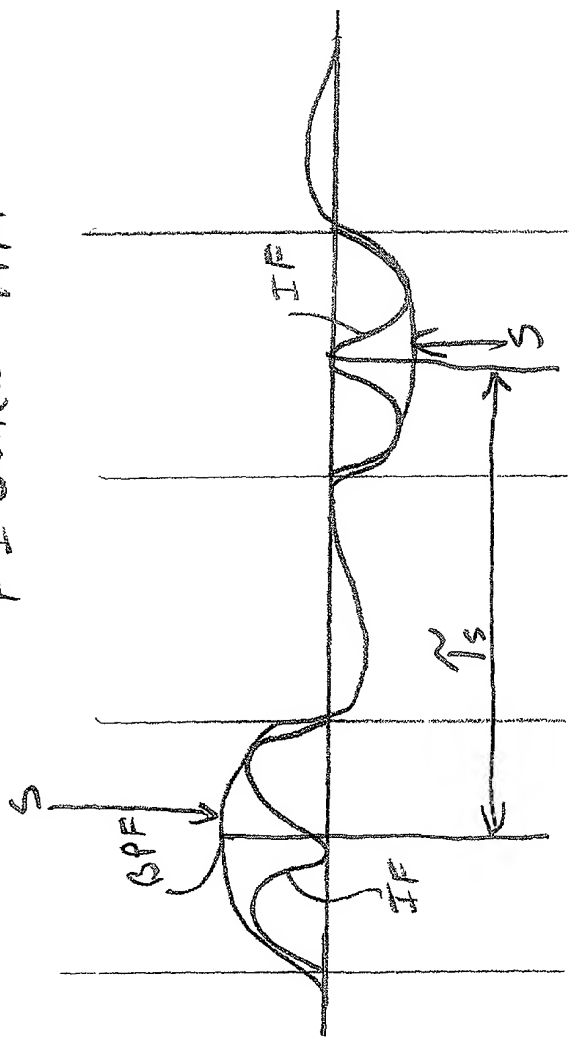
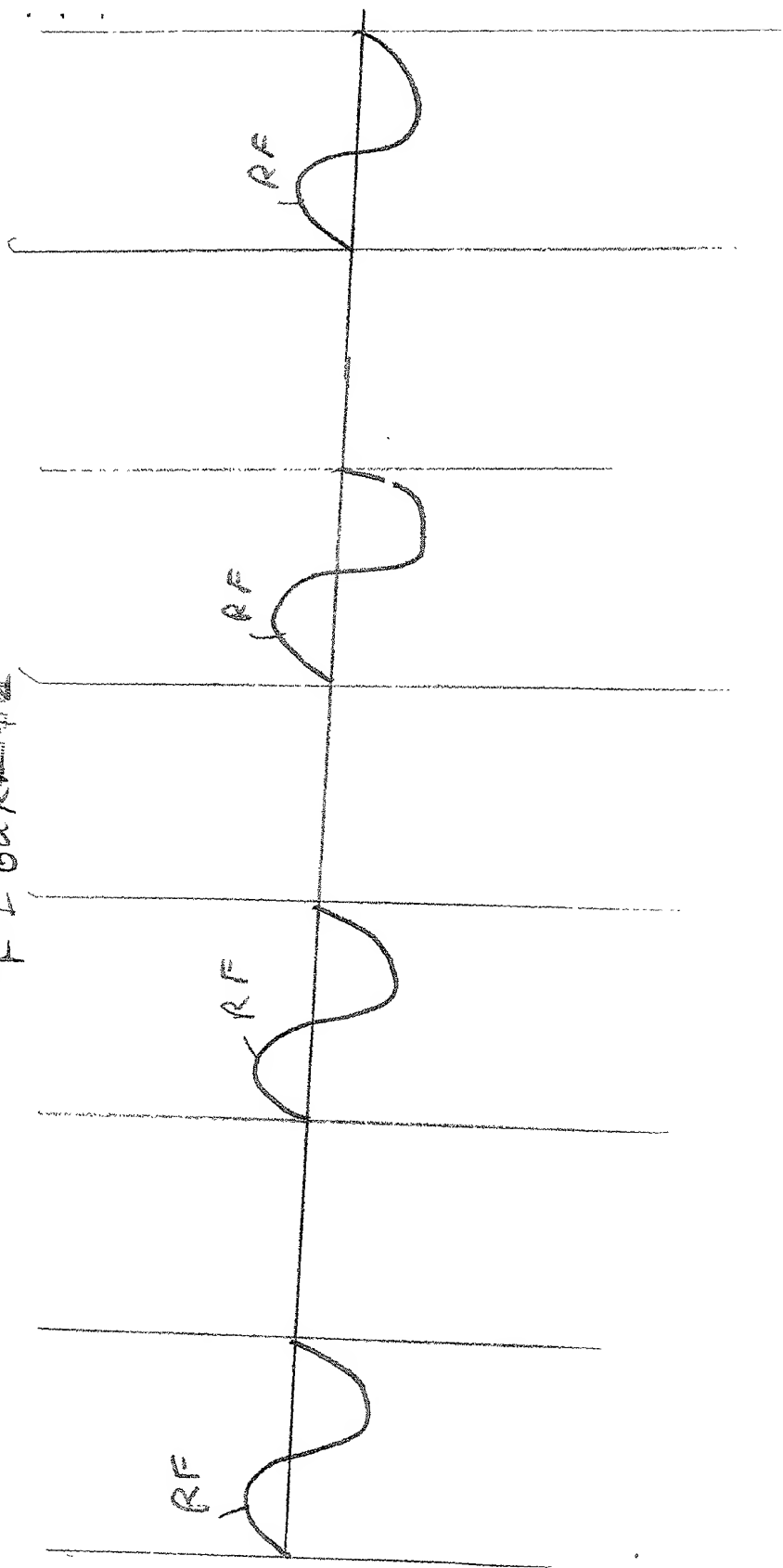


FIGURE 11B



000707 "F 62900042



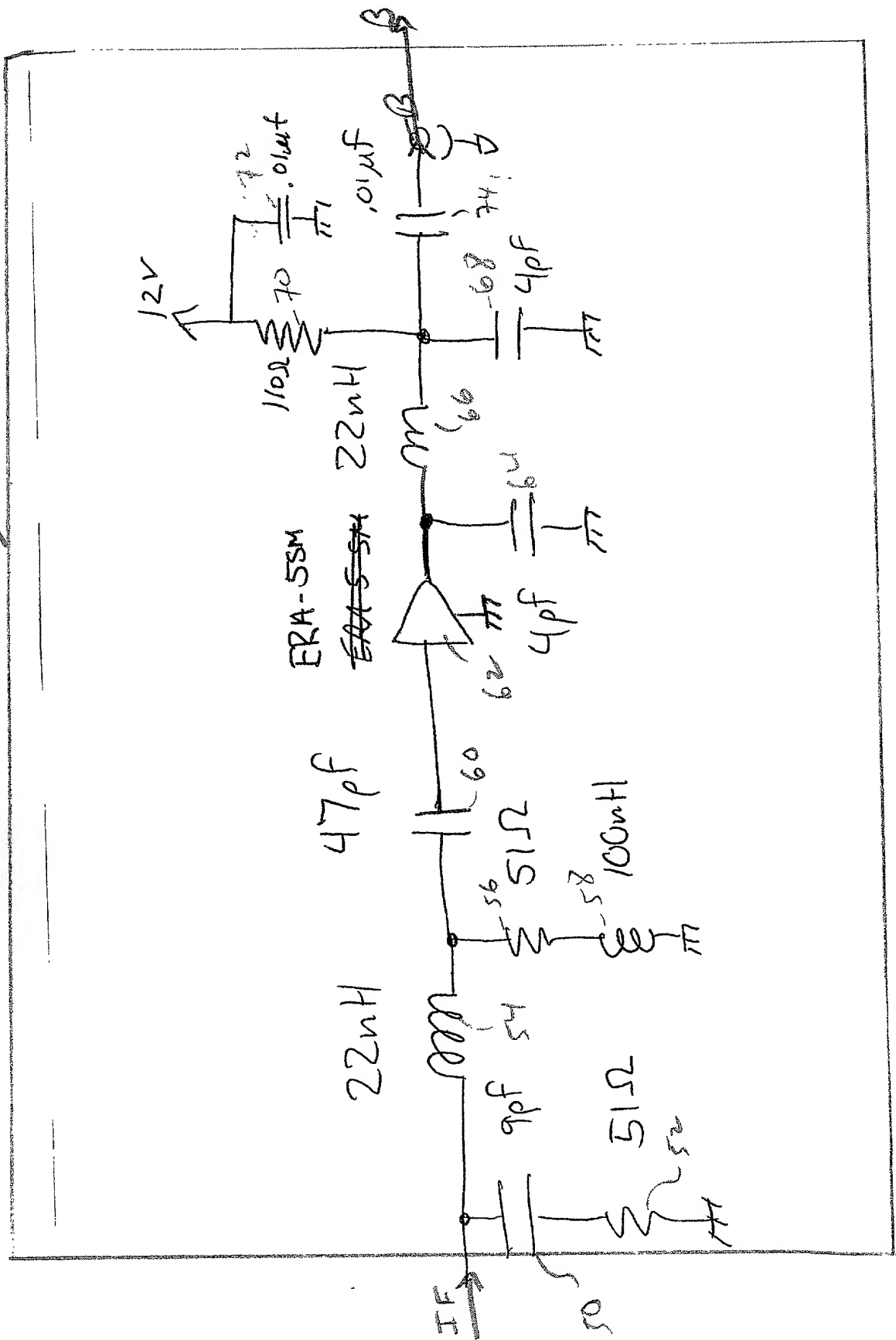
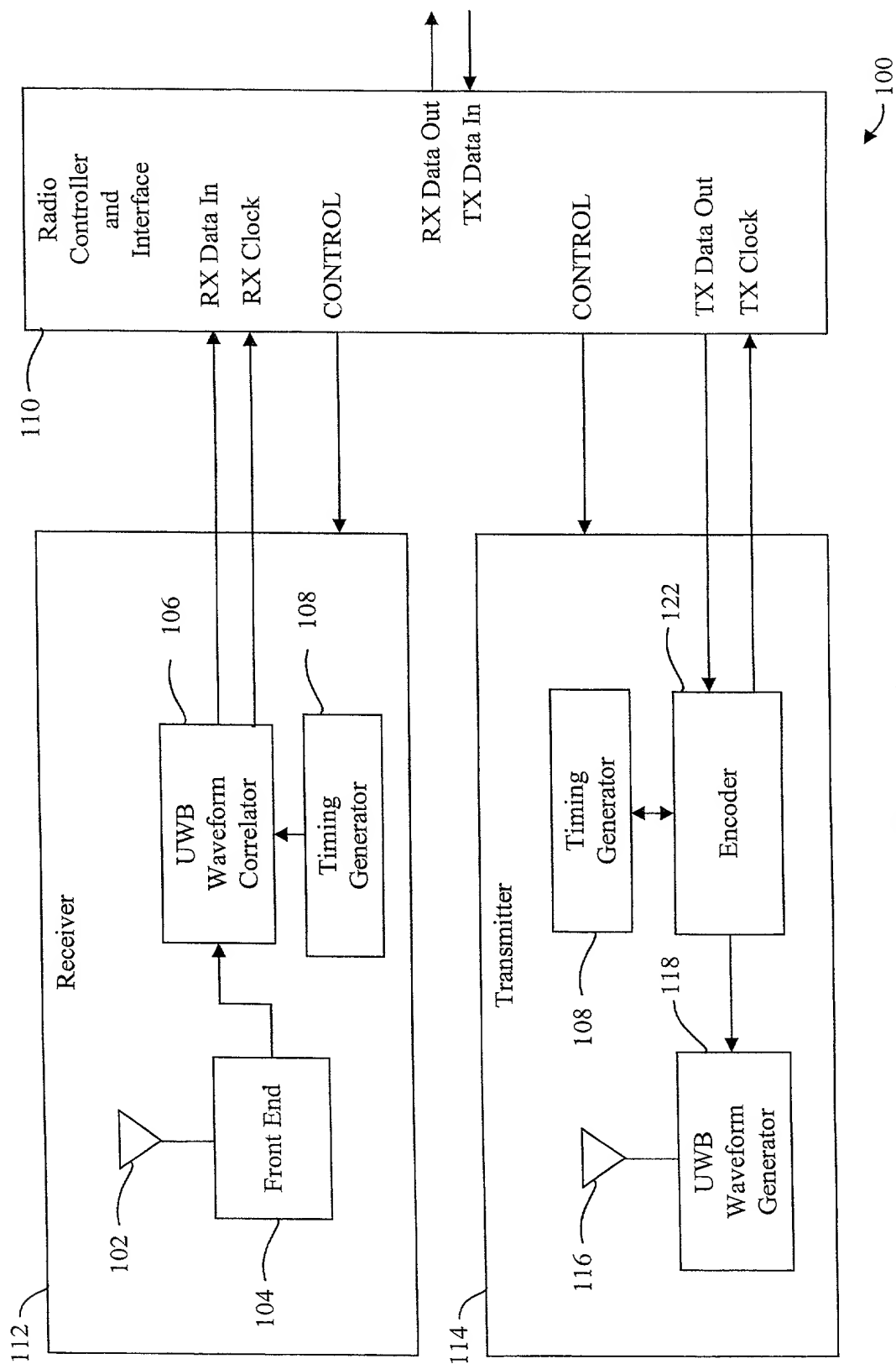




FIGURE 14

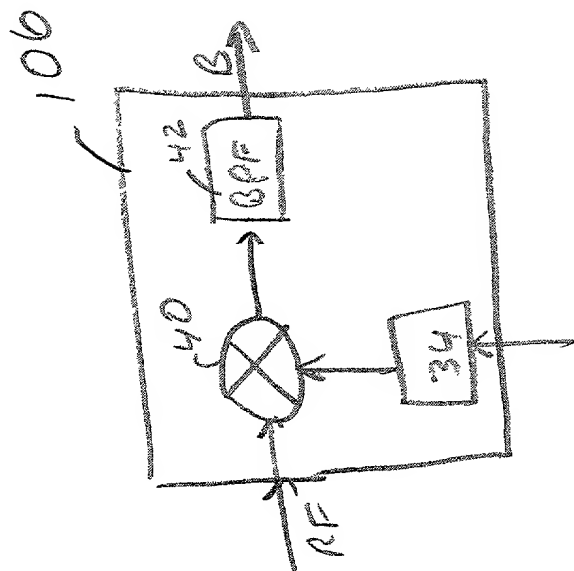
90

| RF | LO | RECEIVER<br>CORRELATOR 30 | RECEIVER<br>CORRELATOR 10 |
|----|----|---------------------------|---------------------------|
| 1  | 1  | +IV                       | 1+a                       |
| 0  | 0  | +IV                       | 1-b                       |
| 1  | 0  | -IV                       | -1-b                      |
| 0  | 1  | IV                        | -1+a                      |



*Figure 15*

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